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(54) **SYSTEMS AND METHODS FOR APPLYING DIRECTED ENERGY TO AN OBJECT**

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CPC ***G02F 1/353*** (2013.01)

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CPC F21Y 2113/00; G02F 1/353–1/3538; G02F 2001/354–2001/3542; G02F 2/00–2/02; H05B 35/00; A61N 5/062; A61N 2005/0642; A61N 2005/0636; A61N 5/0624; A61N 5/0601; A61N 5/0603; A61N 5/00–5/045; A61N 5/0625; H01S 5/4087; H01S 5/4012
USPC 362/230–231, 234; 342/13–20
See application file for complete search history.

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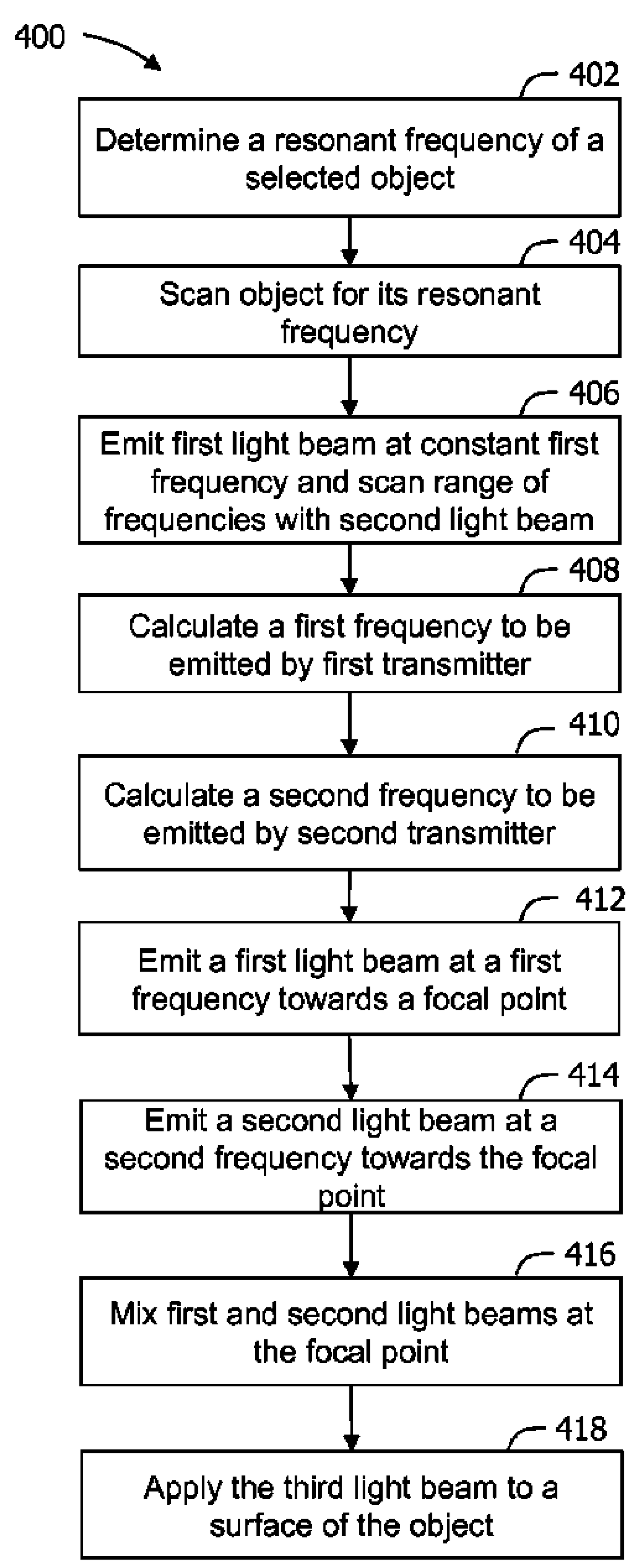
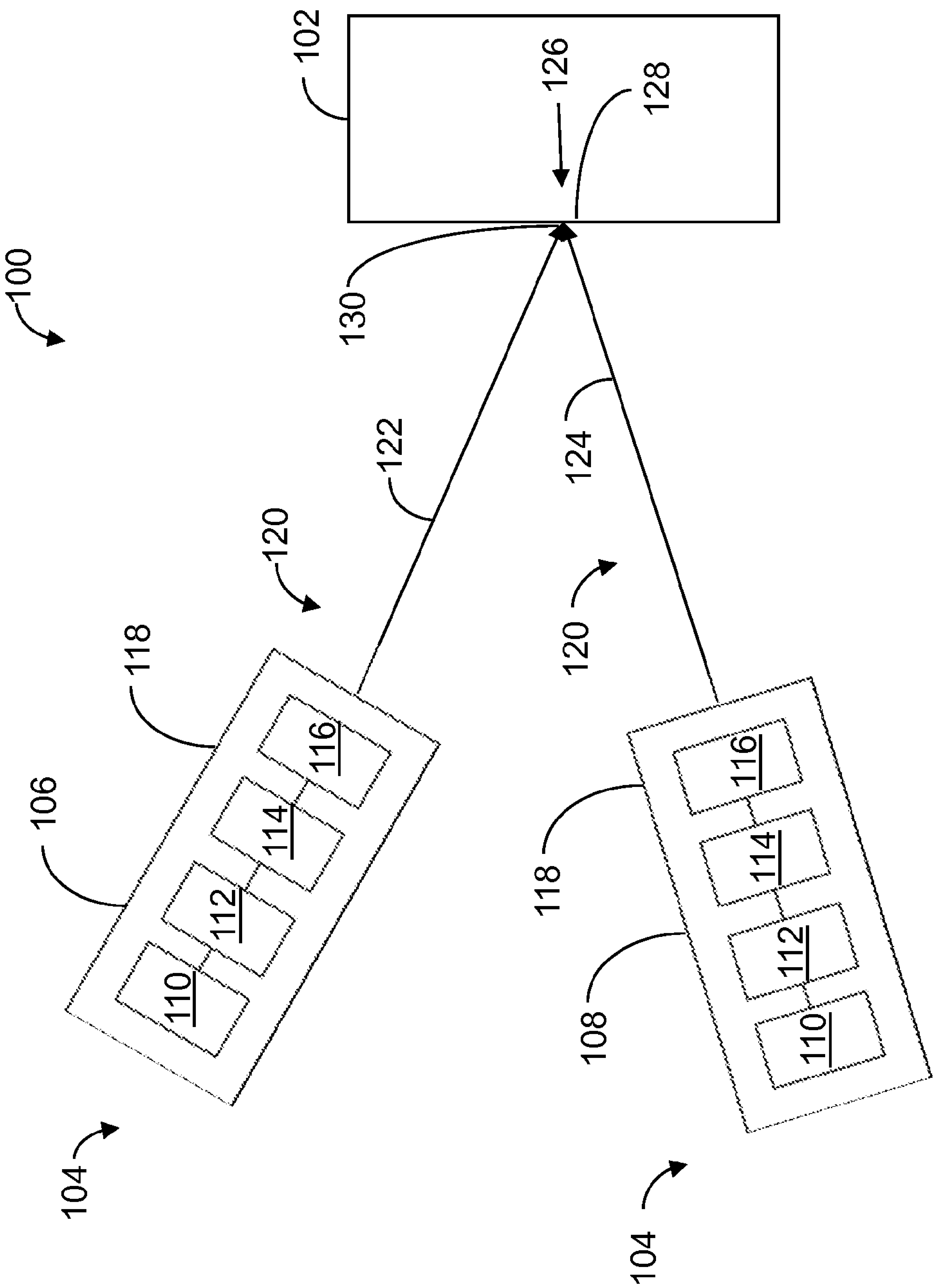
(57) **ABSTRACT**

Systems and methods are provided for applying directed energy to an object. The system includes a first transmitter comprising a light source configured to emit a first light beam at a first frequency towards a focal point and a second transmitter comprising a light source configured to emit a second light beam at a second frequency towards the focal point. The first and second light beams cause a third light beam to be generated that has a third frequency that is coincident with at least one resonant frequency of the object.

19 Claims, 4 Drawing Sheets




100
102
126
128
130
122
124
120
120
118
118
106
108
110
112
114
116
110
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104
104

FIG. 1

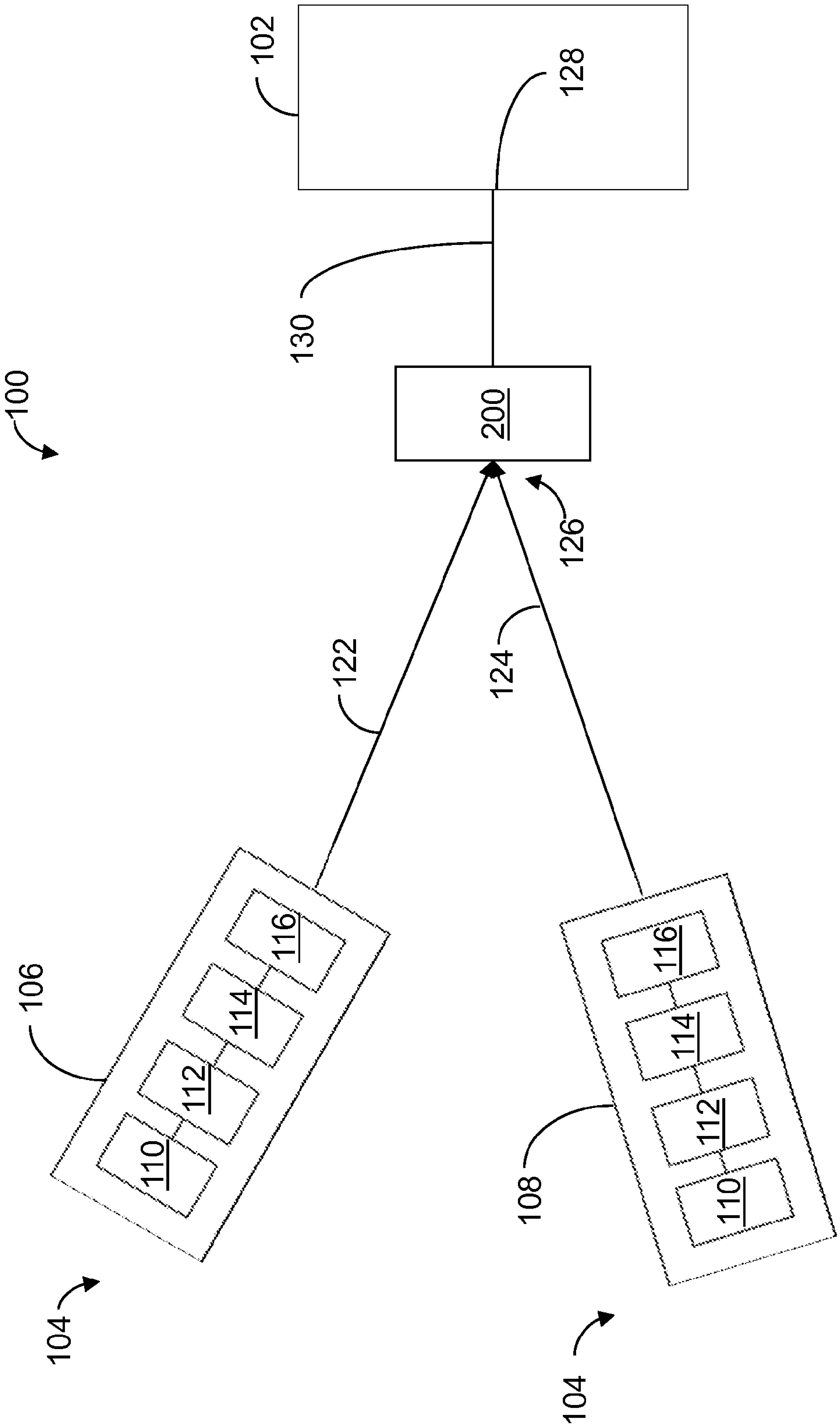
102
128
130
100
200
126
122
124
106
116
114
112
110
108
116
114
112
110
104
104

FIG. 2

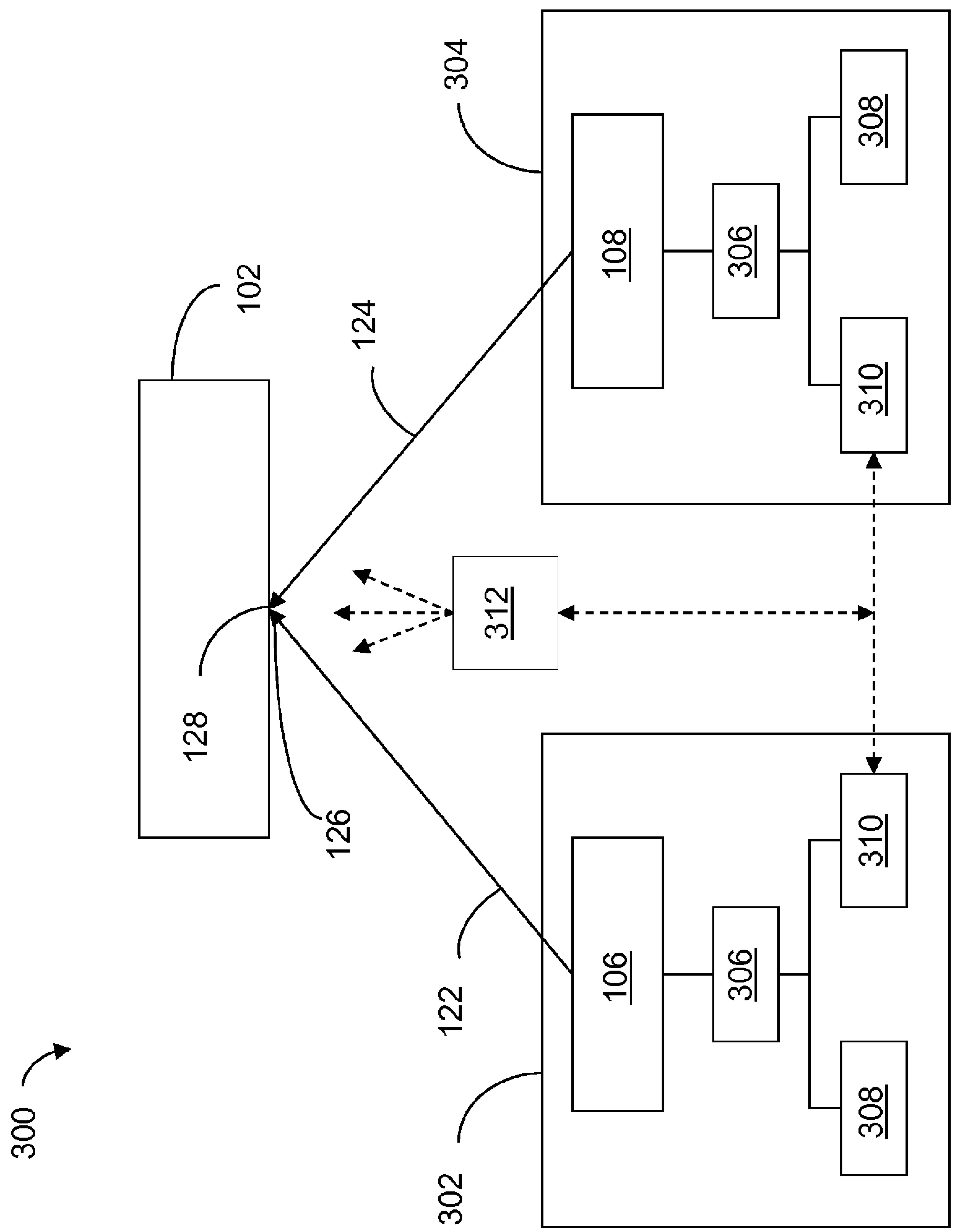
300
102
124
304
108
306
308
310
312
128
126
122
106
306
310
308
302

FIG. 3

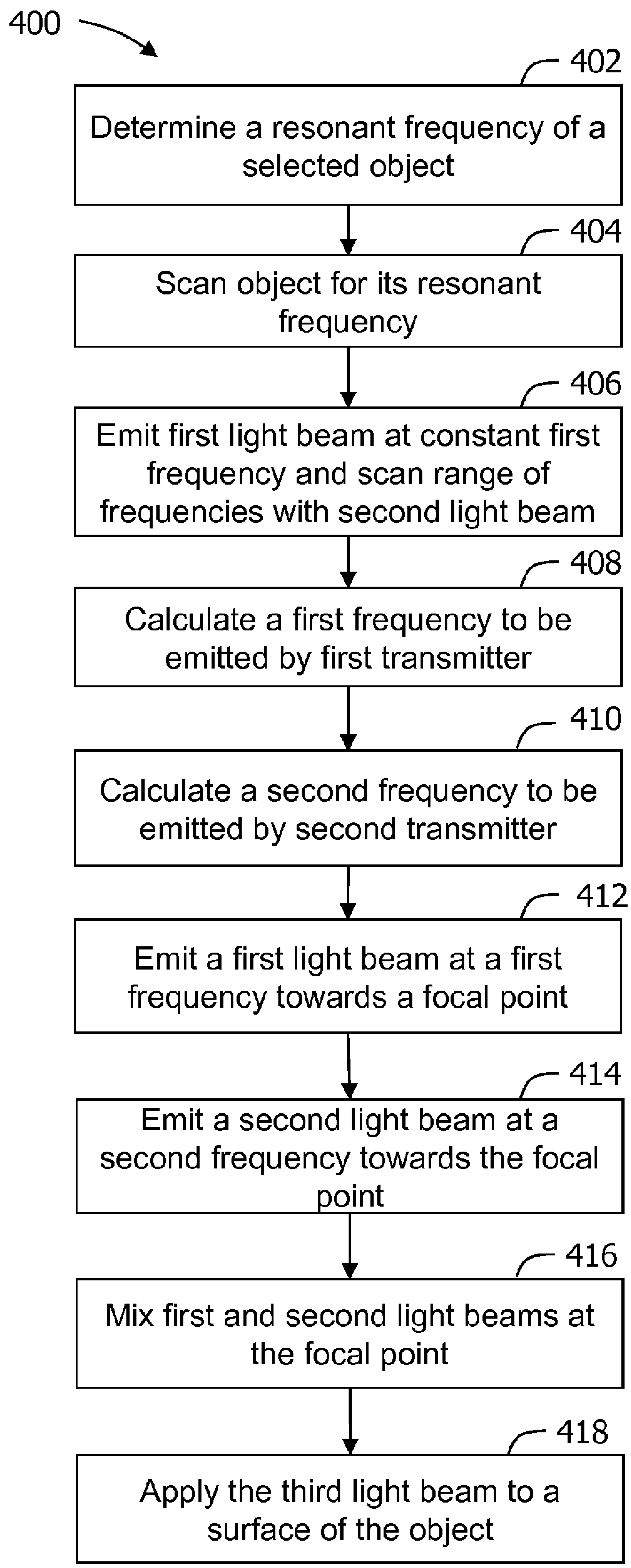
400
402
Determine a resonant frequency of a selected object
404
Scan object for its resonant frequency
406
Emit first light beam at constant first frequency and scan range of frequencies with second light beam
408
Calculate a first frequency to be emitted by first transmitter
410
Calculate a second frequency to be emitted by second transmitter
412
Emit a first light beam at a first frequency towards a focal point
414
Emit a second light beam at a second frequency towards the focal point
416
Mix first and second light beams at the focal point
418
Apply the third light beam to a surface of the object

FIG. 4

SYSTEMS AND METHODS FOR APPLYING DIRECTED ENERGY TO AN OBJECT

BACKGROUND

The field of the disclosure relates generally to light-based directed energy systems, and more specifically, to methods and systems for applying directed energy to an object.

At least some known directed energy systems use light beams to apply directed energy to an object and/or to alter a physical characteristic of the object. One method used to alter a physical characteristic of an object involves operating a directed energy system to interact with a resonant frequency of the object. For example, known directed energy sources include high-powered lasers, such as a chemical oxygen iodine laser (COIL), a hydrogen fluoride (HF) laser, and/or a deuterium fluoride (DF) laser. Such directed energy sources are single frequency directed energy sources that typically emit wavelengths in the infrared region.

However, the use of known single frequency directed energy sources is limited because the sources that generate high power are not usually naturally coincident with resonant frequencies that cause high levels of conditional change of the object. As such, known directed energy systems may be inefficient and/or ineffective at altering a physical characteristic of an object.

BRIEF DESCRIPTION

In one aspect, a system is provided for applying directed energy to an object. The system includes a first transmitter comprising a light source configured to emit a first light beam at a first frequency towards a focal point and a second transmitter comprising a light source configured to emit a second light beam at a second frequency towards the focal point. The first and second light beams cause a third light beam to be generated that has a third frequency that is coincident with at least one resonant frequency of the object.

In another aspect, a method of applying directed energy to an object is provided. The method includes emitting a first light beam at a first frequency towards a focal point, and emitting a second light beam at a second frequency towards the focal point. The method also includes mixing the first and second light beams to cause a third light beam to be generated that has a third frequency that is coincident with at least one resonant frequency of the object and applying the third light beam to a surface of the object.

The features, functions, and advantages that have been described herein can be achieved independently in various embodiments or may be combined in yet other embodiments, further details of which can be seen with reference to the following description and drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** illustrates an exemplary directed energy system that may be used to apply directed energy on an object and/or that may be used to change a physical characteristic of the object.

FIG. **2** illustrates an exemplary directed energy system including a non-linear mixing device that is used to mix the light beams before a beam is applied to the object.

FIG. **3** illustrates an alternative directed energy system that may be used to apply directed energy on an object and/or that may be used to change a physical characteristic of the object.

FIG. **4** is a flow diagram of an exemplary method that may be executed to apply directed energy to an object.

DETAILED DESCRIPTION

FIG. **1** illustrates an exemplary directed energy system **100** that may be used to apply directed energy on an object **102**, and/or that may be used to alter a physical characteristic of object **102**. In the exemplary embodiment, directed energy system **100** includes at least one transmitter **104**. More specifically, in the exemplary embodiment, directed energy system **100** includes a first transmitter **106** and a second transmitter **108**. Alternatively, directed energy system **100** may include any number of transmitters **104** that enables directed energy system **100** to function as described herein. Object **102** may be, but is not limited to only being, a vehicle, a building, a person, or any other object that may be least partially interact with light.

Unless otherwise specified, transmitters **104** are substantially identical, and each includes a light source **110**, an output intensity control module **112**, an output frequency control module **114**, and an output polarization control module **116** that are each positioned within a housing **118**. Light source **110** generates a light beam **120** that is emitted from transmitter **104**. In the exemplary embodiment, light source **110** is a laser. Alternatively, light source **110** may be any other source that enables transmitter **104** to generate a light beam **120** as described herein.

Output intensity control module **112** is coupled to light source **110**. Output intensity control module **112** receives light beam **120** from light source **110** and selectively controls and/or adjusts an intensity of light beam **120**. In the exemplary embodiment, output intensity control module **112** includes a feedback system that controls and/or adjusts the intensity of light beam **120** and outputs light beam **120** at a predetermined intensity. Alternatively, output intensity control module **112** may include any other device that enables transmitter **104** to control the intensity of light beam **120** as described herein.

Output frequency control module **114** is coupled to output intensity control module **112**. Output frequency control module **114** receives light beam **120** from output intensity control module **112** and controls and/or adjusts a frequency of light beam **120**. In the exemplary embodiment, output frequency control module **114** includes an etalon, a passive grating, and/or an optical filter. Alternatively, output frequency control module **114** may include any other device that enables transmitter **104** to control and/or adjust the frequency of light beam **120** as described herein.

Output polarization control module **116** is coupled to output frequency control module **114** and receives light beam **120** emitted from output frequency control module **114** and controls and/or adjusts a polarization of light beam **120**. In the exemplary embodiment, output polarization control module **116** includes a polarizer (not shown) and/or a wave plate (not shown). Alternatively, output polarization control module **116** may include any other device that enables transmitter **104** to control and/or adjust the polarization of light beam **120** as described herein.

In the exemplary embodiment, first transmitter **106** and second transmitter **108** emit light beams **122** at the same or at different frequencies. More specifically, in the exemplary embodiment, first transmitter **106** emits a first light beam **122** at a first frequency, and second transmitter **108** emits a second light beam **124** at a second frequency. Each light beam **122** and **124** is directed towards the same location or focal point **126**. In the exemplary embodiment, focal point is on a surface **128** of object **102** such that first light beam **122** and second light beam **124** at least partially interact on surface **128**.

First light beam **122** and/or second light beam **124** interact with each other at surface **128** such that material excitations are generated on surface **128**. The interaction with respect to first light beam **122** and/or second light beam **124** on surface **128** generates an effective energy transfer that facilitates a more expedient change in the physical state of object **102**. In some embodiments, first and second light beams **122** and **124** interact with a resonant frequency of object **102** to generate sufficient material excitations to physically destroy object **102**.

As used herein, the interaction between first light beam **122**, second light beam **124**, and surface **128** of object **102** causes a third light beam **130** to be generated with a third frequency that is different from the frequency of the light beams received at the surface.

In the exemplary embodiment, the interaction of light beams **122** and **124** non-linear response of surface **128** causes a third light beam **130** to be generated at focal point **126**. Beam **130** has a second harmonic frequency relative to first light beam **122** and of second light beam **124** that is approximately two times the frequency of first light beam **122** and/or second light beam **124**. Moreover, third light beam **130** has a second order combination (i.e., a second order effect) as compared to first light beam **122** and second light beam **124**. The second order effect may cause third light beam **130** to have a frequency that is approximately equal to a sum of the frequencies of first light beam **122** and second light beam **124**, or a frequency that is approximately equal to a difference between the frequencies of first light beam **122** and second light beam **124**. Alternatively or additionally, the frequency of third light beam **130** may be generated at any other non-linear combination relative to first light beam **122** and/or second light beam **124**.

FIG. **2** illustrates an exemplary directed energy system **100** including a non-linear mixing device **200** that is used to mix light beams **122** and **124** to generate a third light beam **130** that is emitted towards object **102**. Unless otherwise specified, similar components are identified in FIG. **2** with the same reference numerals used in FIG. **1**.

In the exemplary embodiment, directed energy system **100** includes transmitters **106** and **108** and non-linear mixing device **200**. Non-linear mixing device **200** is between object **102** and first and second transmitters **106** and **108** to enable mixing device **200** to receive first and second light beams **122** and **124** and to enable third light beam **130** to be emitted towards object **102**. Non-linear mixing device **200** may be manufactured from known non-linear optical crystals, which include, but are not limited to only including, β-barium borate, lithium iodate, potassium niobate, monopotassium phosphate, lithium triborate, potassium titanyl phosphate, lithium niobate, and ammonium dihydrogen phosphate.

In the exemplary embodiment, the interaction of beams **122** and **124** causes a third light beam **130** to be generated with a harmonic frequency that is different than that of beams **122** and **124** (i.e., a frequency that is approximately two times the frequency of beams **122** and **124**), and/or third light beam **130** has a second order combination (i.e., a second order effect) as compared to beams **122** and **124**. The second order effect may cause third light beam **130** to have a frequency that is approximately equal to a sum of the frequencies of beams **122** and **124**, and/or a frequency that is approximately equal to a difference between the frequencies of beams **122** and **124**. Alternatively or additionally, the frequency of third light beam **130** may be at any other combination of the frequencies of beams **122** and **124**.

Non-linear mixing device **200** guides and emits third light beam **130** towards object surface **128** such that beam **130** interacts with surface **128** in a non-linear fashion to create material excitations across a part of surface **128**. The interaction on surface **128** creates an effective energy transfer that facilitates a change in the physical state of object **102**. More specifically, an efficiency of system **100** is facilitated to be enhanced and increased as compared to at least some known directed energy systems.

FIG. **3** illustrates an alternative directed energy system **300** that may be used to apply directed energy on an object **102** and/or that may be used to change a physical characteristic of object **102**. Directed energy system **300** is similar to directed energy system **100** (shown in FIG. **1**), and similar components are identified in FIG. **3** with the same reference numerals used in FIG. **1**.

In the exemplary embodiment, directed energy system **300** includes a first transmitter system **302** and a second transmitter system **304**. First transmitter system **302** includes first transmitter **106**, and second transmitter system **304** includes second transmitter **108**. Moreover, first transmitter system **302** and second transmitter system **304** each includes a processor **306**, a memory **308**, and a communication device **310** for use in communicating with each other.

Processor **306** includes any suitable programmable circuit including one or more systems and microcontrollers, microprocessors, reduced instruction set circuits (RISC), application specific integrated circuits (ASIC), programmable logic circuits (PLC), field programmable gate arrays (FPGA), and any other circuit capable of executing the functions described herein. The above examples are exemplary only, and thus are not intended to limit in any way the definition and/or meaning of the term "processor."

Memory **308** includes a computer readable storage medium, such as, without limitation, random access memory (RAM), flash memory, a hard disk drive, a solid state drive, a diskette, a flash drive, a compact disc, a digital video disc, and/or any suitable memory. In the exemplary embodiment, memory **308** includes data and/or instructions that are executable by processor **306** to enable processor **306** to perform the functions described herein.

Communication device **310** may include, without limitation, a radio frequency (RF) transceiver, a network interface controller (NIC), a network adapter, and/or any other communication device that enables directed energy system **300** to operate as described herein. Communication devices **310** transmit data to, and receive from, with each other using any suitable communication protocol.

In the exemplary embodiment, data is transmitted between transmitter systems **302** and **304** to facilitate applying directed energy to object **102**. For example, first transmitter system **302** may transmit, to second transmitter system **304**, a frequency at which first transmitter system **302** emits first light beam **122**. Additionally or alternatively, second transmitter system **304** may transmit, to first transmitter system **302**, a frequency at which second transmitter system **304** emits second light beam **124**. Processor **306** of first transmitter system **302** and/or of second transmitter system **304** may calculate the frequencies at which to emit beams **122** and **124** such that when mixed at focal point **126**, beams **122** and **124** interact with object **102** at its resonant frequency.

In one embodiment, a frequency of light beam **122** is controlled or selected by processor **306** of first transmitter system **302** to reduce an interference with ambient air or an ambient environment. Moreover, processor **306** may communicate, via communication devices **310**, position and/or aim of transmitter systems **302** and **304** with respect to object **102** to facilitate aligning beams **122** and **124**. Additionally or alternatively, any other data may be transmitted between transmitter systems **302** and **304**.

In an alternative embodiment, directed energy system **300** includes an object monitoring system **312** communicatively coupled to communication devices **310**. Object monitoring system **312** monitors and/or senses various characteristics relating to object **102** and communicates them to directed energy system **300**. For example, object monitoring system **312** may monitor whether beams **122** and **124** are interacting at focal point **126**. If interaction is not occurring, object monitoring system **312** communicates with communication devices **310** to adjust the aim of transmitter system **302** and/or **304**. Object monitoring system **312** may also monitor physical characteristics of object **102** to determine and communicate a status of a variety of operating parameters, including but not limited to, health and/or physical state of object **102**, whether and/or to what extent beams **122** and **124** at their designated frequencies are altering physical characteristics of object **102**, and whether any foreign objects such as humans or vehicles enter a predetermined radius of danger with respect to object **102**.

During operation, in the exemplary embodiment, a particular object **102** to be altered is selected and at least one resonant frequency is determined for object **102**. In one embodiment, resonant frequency information for specific objects **102** is stored in a database or library that can be accessed by a user. In another embodiment, directed energy system **100** may use transmitters **106** and **108** to scan object **102** for its resonant frequency. More specifically, first transmitter **106** emits first light beam **122** at a substantially constant first frequency, while second transmitter **108** scans a range of frequencies using second light beam **124** until the resonant frequency of object **102** is determined.

In the exemplary embodiment, first transmitter system **302** uses first transmitter **106** to emit a first light beam **122** towards focal point **126**, which may be a point on surface **128** of object **102** or a point on non-linear mixing device **200**. Second transmitter system **304** emits a second light beam **124** towards focal point **126**. Beams **122** and **124** interact to generate third light beam **130** with a third frequency that is different that the frequencies of beams **122** and **124**. Third beam **130** interacts with a resonant frequency of object **102** to generate material excitations on surface **128** and to facilitate a more expedient change in the physical state of object **102**.

FIG. **4** is a flow diagram of an exemplary method **400** that may be used to direct energy to object **102** and that may be used with directed energy system **100** (shown in FIG. **1**) and/or **300** (shown in FIG. **3**). In the exemplary embodiment, method **400** is at least partially executed by a processor, such as processor **306** (shown in FIG. **3**).

In the exemplary embodiment, method **400** includes determining **402** at least one resonant frequency of a selected object **102** (shown in FIGS. **1**, **2**, and **3**). In one embodiment, resonant frequency information for specific objects **102** is stored in a database or library. In another embodiment, directed energy system **100** scans **404** object **102** to determine its resonant frequency. More specifically, in such an embodiment, first light beam **122** is emitted **406** at a substantially constant first frequency, while scanning a range of frequencies using second light beam **124**.

In the exemplary embodiment, a processor **306** calculates **408** a first frequency to be emitted by first transmitter **106** and calculates **410** a second frequency to be emitted by second transmitter **108**, based on the resonant frequency returned for object **102**.

First light beam **122** having a first frequency is emitted **412** towards a predetermined focal point **126**. Second light beam **124** is emitted **414** at a second frequency towards focal point **126**. In one embodiment, beams **122** and **124** are focused on surface **128**. In another embodiment, beams **122** and **124** are focused towards non-linear mixing device **200**.

Beams **122** and **124** are mixed **416** at focal point **126** to generate a third light beam **130** having a third frequency that is coincident with at least one resonant frequency of object **102**. In one embodiment, mixing beams **122** and **124** causes a third frequency to be generated that is a non-linear combination of the first frequency and the second frequency. In another embodiment, beams **122** and **124** are mixed to interact non-linearly with each other and with surface **128** to generate a third frequency that is a second order combination of the first and second frequencies. In such an embodiment, the third frequency may be one of a sum of the first and second frequencies and a harmonic of the first and second frequencies. In the exemplary embodiment, the third light beam **130** is then applied **418** to surface **128** to facilitate applying directed energy at object **102** and/or changing a physical characteristic of object **102**.

The directed energy system described herein enables directed energy to be applied to an object and/or enables a physical characteristic of an object to be changed in a robust and efficient manner. The directed energy system emits a first light beam at a first frequency and a second light beam at a second frequency towards a focal point, wherein the beams are mixed non-linearly with a surface of the object. The interaction of the surface and the light beams creates material excitations on the object that creates an alteration and/or destruction of the object. The frequencies of the first and second light beams may be selected to be coincident with resonances in the object, so energy transfer may occur more effectively, and such that a rapid change in the physical characteristic of the object may occur. In addition, the frequencies of the first and second light beams may be selected to facilitate reducing environmental scattering and/or absorption, in conjunction with the non-linear response of the surface to the light beams. As such, an efficiency of the directed energy system may be increased as compared to at least some prior art systems.

Exemplary embodiments of directed energy systems and methods for applying directed energy to an object are described above in detail. The directed energy systems and the methods are not limited to the specific embodiments described herein but, rather, components of the systems and/or steps of the methods may be utilized independently and separately from other components and/or steps described herein. Further, the described operations and/or components may also be defined in, or used in combination with, other systems, methods, and/or devices, and are not limited to practice with only the directed energy system as described herein.

Although the present embodiments are described in connection with applying directed energy to an object, the embodiments are operational to detect or determine other aspects or characteristics of objects. The directed energy systems described herein are not intended to suggest any limitation as to the scope of use or functionality of any aspect of the disclosure. In addition, the directed energy systems described herein should not be interpreted as having any dependency or requirement relating to any one or combination of components illustrated in the exemplary operating environment.

The order of execution or performance of the operations in the embodiments of the invention illustrated and described herein is not essential, unless otherwise specified. That is, the operations may be performed in any order, unless otherwise specified, and embodiments of the invention may include additional or fewer operations than those disclosed herein. For example, it is contemplated that executing or performing a particular operation before, contemporaneously with, or after another operation is within the scope of aspects of the invention.

Although specific features of various embodiments of the invention may be shown in some drawings and not in others, this is for convenience only. In accordance with the principles of the invention, any feature of a drawing may be referenced and/or claimed in combination with any feature of any other drawing.

This written description uses examples to disclose various embodiments, which include the best mode, to enable any person skilled in the art to practice those embodiments, including making and using any devices or systems and performing any incorporated methods. The patentable scope is defined by the claims, and may include other examples that occur to those skilled in the art. Such other examples are intended to be within the scope of the claims if they have structural elements that do not differ from the literal language of the claims, or if they include equivalent structural elements with insubstantial differences from the literal languages of the claims.

What is claimed is:

1. A system for applying directed energy to an object, said system comprising:

a first transmitter comprising a light source configured to emit a first light beam at a first frequency towards a focal point; and

a second transmitter comprising a light source configured to emit a second light beam at a second frequency towards the focal point, the second transmitter configured to scan a range of frequencies using the second light beam, the second light beam emitted to cause a third light beam to be generated that has a third frequency that is coincident with at least one resonant frequency of the object, wherein at least one of the first transmitter and the second transmitter is configured to determine the at least one resonant frequency of the object.

2. A system in accordance with claim **1**, wherein said first and second transmitters emit towards the focal point located on a surface of the object.

3. A system in accordance with claim **1**, wherein said first and second transmitters emit towards the focal point located on a non-linear mixing device.

4. A system in accordance with claim **1**, wherein the first light beam and the second light beam interact non-linearly with each other and with a surface of the object to generate the third frequency.

5. A system in accordance with claim **4**, wherein the non-linear combination of the first frequency and the second frequency is a second order combination of the first frequency and the second frequency.

6. A system in accordance with claim **5**, wherein the second order combination of the first frequency and the second frequency is a sum of the first frequency and the second frequency.

7. A system in accordance with claim **5**, wherein the second order combination of the first frequency and the second frequency is a harmonic of the first frequency and the second frequency.

8. A system in accordance with claim **1**, wherein the first and second transmitters are configured to determine the resonant frequency of the object.

9. A system in accordance with claim **8**, wherein at least one of the first transmitter and the second transmitter is configured to calculate the first and second frequencies to be emitted based on the determined resonant frequency.

10. A system in accordance with claim **8**, wherein the first transmitter is configured to emit the first light beam at a substantially constant first frequency.

11. A method of applying directed energy to an object, said method comprising:

emitting a first light beam at a first frequency towards a focal point;

emitting a second light beam at a second frequency towards the focal point;

determining the resonant frequency of the object by scanning a range of frequencies using the second light beam;

mixing the first and second light beams to cause a third light beam to be generated that has a third frequency that is coincident with at least one resonant frequency of the object; and

applying the third light beam to a surface of the object.

12. A method in accordance with claim **11**, further comprising emitting the first and second light beams towards the focal point located on a surface of the object.

13. A method in accordance with claim **11**, further comprising emitting the first and second light beams towards the focal point located on a non-linear mixing device.

14. A method in accordance with claim **11**, further comprising causing the first light beam and the second light beam to interact non-linearly with each other and with the surface to generate the third frequency.

15. A method in accordance with claim **14**, further comprising causing the first light beam and the second light beam to interact non-linearly with each other and with the surface to generate the third frequency that is a second order combination of the first frequency and the second frequency.

16. A method in accordance with claim **15**, wherein generating the third frequency comprises generating the third frequency that is a sum of the first frequency and the second frequency.

17. A method in accordance with claim **15**, wherein generating the third frequency comprises generating the third frequency that is a harmonic of the first frequency and the second frequency.

18. A method in accordance with claim **11**, further comprising calculating the first and second frequencies to be emitted based on the determined resonant frequency.

19. A method in accordance with claim **11**,

further comprising determining the resonant frequency of the object by emitting the first light beam at a substantially constant first frequency.

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